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Sagging of the Dead Sea basin: geometry of the southern and northern ends

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The main structural elements of the Dead Sea Basin (DSB) have been determined with various degrees by a number of researchers. The Basin is an active strike-slip; pull a part basin, which developed along the Dead Sea Rift. The rift is a sinistral transform Fault plate boundary separating the African Plate in the west and the Arabian Plate in the east. The Dead Sea rift is a narrow morphological depression, attributed to a left lateral shear, with a cumulative lateral displacement of about 105 km since its started in the Middle Miocene (Quennel, 1958; Freund et al., 1970; Garfunkel, 1981).

The DSB has formed between sinistral, left-stepping en-echelon strike- slip faults. The step may have migrated northward with time (ten-Brink and Ben-Avraham, 1989), because of a depocenter shift northward (Zak and Freund, 1981; ten-Brink et al. 1999). Its extends from Jabal Er Risha in the south to the Jordan River Delta in the north a few km from the northern end of the Dead Sea shoreline. It is about 135 km long, 10-20 km wide (ten- Brink et al. 1993) and at least 8.5 km deep (Al-Zoubi and ten-Brink, 2001). It is composed of two main segments. The northern 50-km-long part of the basin, the Dead Sea, is a hypersaline lake with a deepest bathymertry of 720 m below sea level (b.s.l.), whereas the southern part of the basin is subaerial with a minimum elevation of

414.5 m b.s.l.

It was proposed that several diagonal faults, such as the Idan, Amazyahu (Khunaizira), and Ein Gedi faults cross the basins at intervals of 20- 30km (Neev and Hall, 1979; Ben-Avraham et al., 1990). The center of the Dead Sea basin has a full graben geometry (Neev and Hall, 1979; Al-Zoubi et al., 2002) indicating that the eastern and the western bounding faults are overlapping and are both active. The eastern bounding fault (Wadi Araba Fault) runs parallel to the Eastern shore of the Dead Sea as a single major basin boundary fault. The narrow intermediate depth " median block" along part of the eastern boundary of the basin (Al-Zoubi and ten-Brink, 2001) is separated from the deep part of the basin by the Ghor Safi fault.

The geophysical data sets used in this study consist of several seismic lines in N-S orientation, gravity data and data from several boreholes (Wadi Ghaube 1, Wadi Arava 1 and Ghor Safi 1 in the southern part of the DSB and JV 1 and JV 2 in the northern end of the DSB.

In the previous studies the Bouguer Gravity Map of the DSB, part of the Bouguer Gravity map of the Dead Sea Rift (ten-Brink et al., 1999 and 2001) shows that the DSB is characterized by a large negative gravity anomaly (maximum of -132 mGal) in the central part of the basin. The gravity map shows a narrow (about 5-7 km wide) anomaly in the southern and northern end which becomes more negative towards to the central part of the basin, suggesting that the basin sags toward its deepest part in the center (ten-Brink et al., 1993; Al-Zoubi and ten-Brink, 2002). The two major faults along the eastern and western sides of the basin are clear, whereas the diagonal faults crossing the basin from the west to the east are not recognized, perhaps due to the thick basin fill. The map shows that there are no indications for diagonal faults at the northern and southern ends of the Dead Sea basin.

The seismic data sets used in this study consist of seismic reflection lines in the north south directions. The previous interpretation of the subsurface structures based on the interpretation of the cross seismic lines in Jordan and Israeli side and correlate them with a small gab. Here we present and interpret three seismic lines with the total length of about 70 km along the axis of the southern part of the Dead Sea basin, line VWJ 8, line 50 and Line 7 and seismic line A in the northern part of the DSB.

In this study we presented the seismic line VWJ 8, where the geological interpretation of the seismic events on line VWJ 8 was carried out by Al-Zoubi & ten-Brink (2002) and based on the lithostratigraphic data obtained from boreholes in the area, Wadi Ghuabe (WG), Arava 1 (e.g., Csato et al., 1997). Arava-1 borehole, drilled in 1959. It penetrated 2650 m of basin fill, consisting of fluvial and lacustrine deposits, and did not reach the basement. The Wadi Ghuabe borehole was drilled in 1989. It penetrated 3200 m of basin fill sediments and did not reach basement. Interpretation indicates that the borehole consists of more than 0.68 km of Miocene sediments, 0.85 km of possibly Pliocene sediments, and about 1.7 km of Quaternary sediments. We choose to interpret the seismic data using the newer borehole (Wadi Ghuabe), which is located closer to Line VWJ-8.

The Miocene sedimentary rocks according to Wadi Ghuabe borehole, thicken northward, and is about 2.2 km thick at the north end of Line VWJ-8.

The most striking feature on seismic Line VWJ-8, which runs parallel to the axis of the basin, is the gradual thickening of the sedimentary section from south to north. The thickening is accomplished without major fault offsets and is most noticeable in the seismic section. Several continuous horizons, A1, A2, B, C, and D, can be traced, based on the stratigraphic relationships of the enclosed units. The shallow units are generally un-faulted on Line VWJ-8, except for a normal fault such as Wadi Ghuabe Fault, which lies close to the previously suggested Iddan Fault (ten Brink and Ben-Avraham, 1989, Gardosh et al., 1997), a diagonal fault across the basin.

The unit bounded by reflectors B and A2 (central unit) thickens uniformly and gradually northward relatively from the center of the Line VWJ-8 and maintains a relatively constant thickness in the southern part of the line. The surface rocks in this area are part of the Miocene Hazeva Formation (Sneh et al., 1998), suggesting that the unit, bounded by reflectors B and A2, is part of the Miocene basin fill. The projected synthetic seismogram of W. Ghuabe well onto Line VWJ-8 confirms the identification of this unit as being of Miocene age.

Horizon B is probably the basement, i.e., the base of the sedimentary fill during the development of the Dead Sea Basin. Thus the basin fill expands from close to zero thickness at the southern end of Line VWJ-8 to 3.1 seconds TWT below the surface (>5 km) at the northern end of this line some 32 - 35 km away without major fault offsets.

Based on the geology in the areas surrounding the central and southern Dead Sea Basin, the reflections underlying Horizon B represent Eocene to Cambrian age sediments with a total thickness of 2-3 km (Bender 1974, Wdowinski and Zilberman, 1997; Sneh, et al., 1998). The seismic sections show that the pre-rift sedimentary section was locally deeply eroded prior to or during the initial stages of basin development. The location of eroded sediments is coincident with the area of local depocenter higher up in the basin fill. It thus appears that the area was first activated in compression and later reactivated in extension. One possibility is that this local area was a push-up structure early in the transform fault history and then changed to a depocenter because of changes in either fault geometry or in relative plate motions (Al-Zoubi & ten-Brink, 2002). Such changes were documented elsewhere along the Dead Sea Transform (ten Brink et al, 1999).

The geological interpretation of the seismic line F in the northern end of the DSB based on the lithostratigraphic data obtained from boreholes Jordan Valley 1 (JV 1) and Jordan Valley 2 (JV 2) and described in detail in Al-Zoubi et al., 2006. There are two major boundaries were identified in the seismic line. The syntectonic sediments reflector R1 (the Cretaceous) and the top Jurassic R2. The thickness between R1 and R2 is characterized by gradual thickening of the sedimentary section from central part of the line (around the surface) in the north to the southern end of the line F, about 0.5 s TWT (Al-Zoubi et al., submitted).

In conclusion, the two seismic lines from the southern and northern ends of the DSB shows gradual thickening of the basin to the center without major vertical offsets in either the basin fill or the underlying strata. The two seismic lines show that the thickness of the basin ranged between zero km in its ends up to several km in the central part.